

The economic feasibility of coconut-oil bio-fuels in the Pacific

Tim Martyn

The declining or insufficient returns from copra farming have forced Pacific producers to seek alternative sources of income. Burning coconut oil as a fuel is a relatively low-valued end use for the coconut. The labour intensiveness of copra production presents an intractable cost frontier that renders coconut bio-fuel projects uneconomic in most parts of the Pacific. Consequently, those communities that have managed to access alternative markets are unlikely to be attracted back to copra. While copra farmers in low-wage locations in remote Melanesia and Micronesia could benefit from local consumption of coconut bio-fuels, there is a need to explore alternative policies to reduce the Pacific's dependence on imported oil, electrify rural areas and increase rural incomes.

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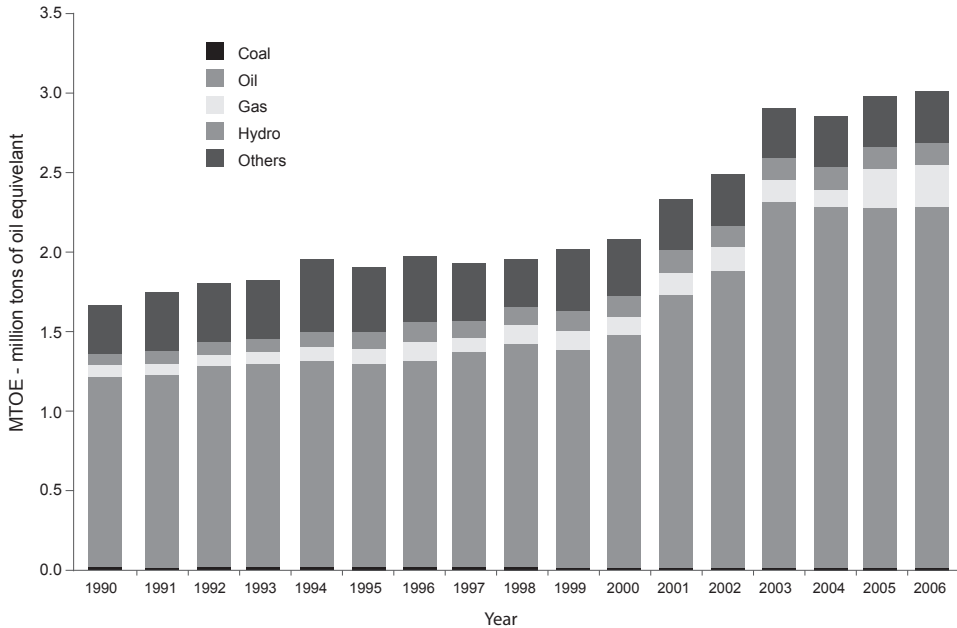
Pacific island countries possessing few indigenous sources of oil and gas (with the exception of Papua New Guinea) are extremely dependent on imported oil to power national development (Figures 1 and 2). Pacific island countries could improve both their energy security and their foreign exchange positions by reducing their dependence on imported oil. This could be achieved by improving their efficiency in the use of oil and by switching to renewable sources of energy (UNDP 2007b).

Why coconut bio-fuels?

Coconut has been an important export crop for the Pacific island countries since the nineteenth century. International demand and prices for traditional coconut products such as copra have, however, retreated in the face of competition from cheaper substitutes (McGregor and Hopa 2008:36). As a result, Pacific island countries have sought to create a new demand for coconut biomass by converting it into coconut oil-based fuels.

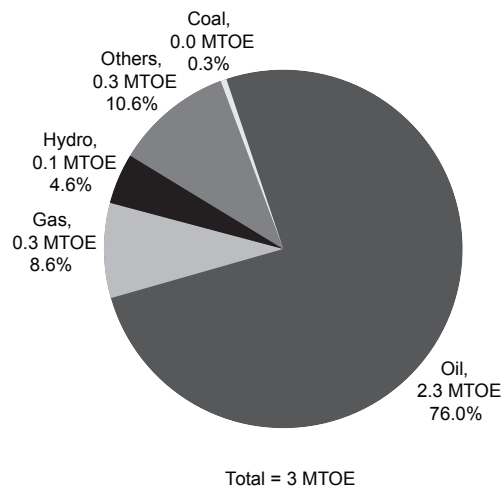


Figure 1 Primary energy supply in the Pacific, 1990–2006



Source: Asia Pacific Energy Research Centre (APERC) and United Nations Statistics Division (UNSD)

Figure 2 Primary energy mix in the Pacific, 2006



Source: Asia Pacific Energy Research Centre (APERC) and United Nations Statistics Division (UNSD)



Pacific governments and donors have tended to pursue one or more policy objectives when it has come to the design and implementation of coconut bio-fuels projects.

1. Reduce dependence on imported fuel and improve the balance of payments: the local production of bio-fuels could contribute to a reduction in the dependence of the Pacific on imports of fuel and thereby make a positive contribution to the balance of payments and energy security.
2. Improve rural income generation: producing and consuming coconut oil as a fuel could provide Pacific farmers with new opportunities to earn an income.
3. Increase rural electrification: production of coconut bio-fuels would present rural and remote communities with a local fuel source and a potential source of electricity.

This article explores, through each of these three policy lenses, why many coconut bio-fuel projects never move 'off the drawing board'. Broadly, they fail to appreciate the changing socioeconomic context in which many Pacific island communities live, leading them to underprice the value of local labour in their feasibility assessments. The low and falling returns to labour provided by copra have pushed producers out of the industry; many of them will never return, and certainly not at the marginal increases to labour offered by coconut bio-fuel projects.

Import substitution

The Pacific Islands Applied Geoscience Commission (SOPAC) estimates that fossil fuel imports accounted for between 8 and 37 per cent of total Pacific island country imports in 2006 and are often equivalent to many times

the total value of exports (Woodruff 2007:4). Pacific island countries' dependence on imported fossil fuels makes them particularly vulnerable to global fuel price spikes—for two main reasons. First, their economies are very energy intensive, meaning that they use a large amount of energy for every dollar of income generated—largely as a result of their dependence on long-distance transportation and the importance of energy-intensive economic activities such as fishing (Dornan 2009:73). Second, electrical power generation in the islands is fuelled largely by diesel (UNDP 2007b:46).

Because of the distance from markets, fuel price increases not only impact on energy costs, they also raise the cost of food, transport, fertilisers and farm inputs, and reduce the competitiveness of Pacific island exports. Subsequently, large oil price rises can significantly increase inflation and weaken the balance of payments (BOP) (Table 1).

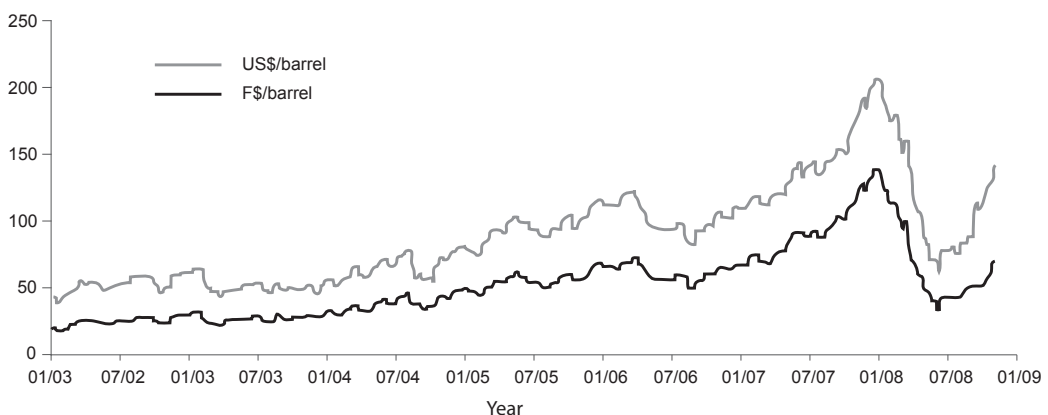
Between June 2007 and June 2008, the price of a barrel of crude oil on the New York Mercantile Exchange (NYMEX) rose from US\$65/barrel to US\$140/barrel—an increase of almost 107 per cent (www.nymex.com, 2009) (Figure 3). The International Energy Agency (IEA) predicts that declining production, coupled with growth in annual demand, will contribute to the oil price reaching an average annual price of US\$120/barrel, in today's dollars, by 2030 (IEA 2008:13).

Given the Pacific region's dependence on imported oil and its vulnerability to high oil prices, it makes sense for Pacific governments to prioritise the substitution of imported fuel with locally produced alternatives where they are available at a cheaper price (REM Meeting 2007). It is not clear, however, whether coconut bio-fuels offer such an alternative. Part of the reason for this uncertainty is that the prices of petroleum products, and that of copra and coconut oil, are increasingly correlated. For example, as the price of imported petroleum products

**Table 1 Pacific island petroleum imports, 2006**

Country	Import value (US\$ millions)	Percentage of total imports	Percentage of total exports
Fiji	340.2	23.5	50.0
Solomon Islands	11.7	27.4	15.8
Samoa	22.6	15.1	160.3
Vanuatu	12.8	14.3	64.3
Federated States of Micronesia	17.3	13.0	88.3
Tonga	17.6	25.5	293.3
Kiribati	5.7	10.0	172.7
Marshall Islands	20.4	37.3	224.2
Cook Islands	6.2	8.4	86.1
Palau	12.4	13.0	104.5

Source: Woodruff, A., 2007. The potential for renewable energy to promote sustainable development in Pacific island countries, Paper prepared for the 30th Conference of the International Association of Energy Economics, Wellington, New Zealand:4.

Figure 3 World oil price, January 2002 to January 2009 (US\$ and F\$/barrel)

Source: Energy Information Administration, 2009, <http://tonto.eia.doe.gov/>



rose in 2007 and 2008, so too did the prices of copra and coconut oil.

Correlation between the world oil price and vegetable-oil prices

The increasing use of vegetable oils as a fuel substitute has led to the increasing correlation between the world oil price and world prices of vegetable oils, including coconut oil (Figure 4).

Any diversion of soybean-oil or palm-oil output to bio-fuel uses affects coconut-oil prices, as less of these substitutes are available to compete with coconut oil in its traditional edible and industrial uses. With the predicted growth in the use of vegetable oils as bio-fuels and fuel additives, this trend is likely to increase (McGregor and Hopa 2008:6). As a result, the presumption that high crude oil prices will make coconut oil more price competitive as a source of bio-fuel is less relevant, as the prices of both become increasingly correlated.

For many Pacific countries, however, another factor stands in the way of displacing a significant proportion of their fuel imports: the transport sector is the largest consumer of imported oil in the Pacific, and

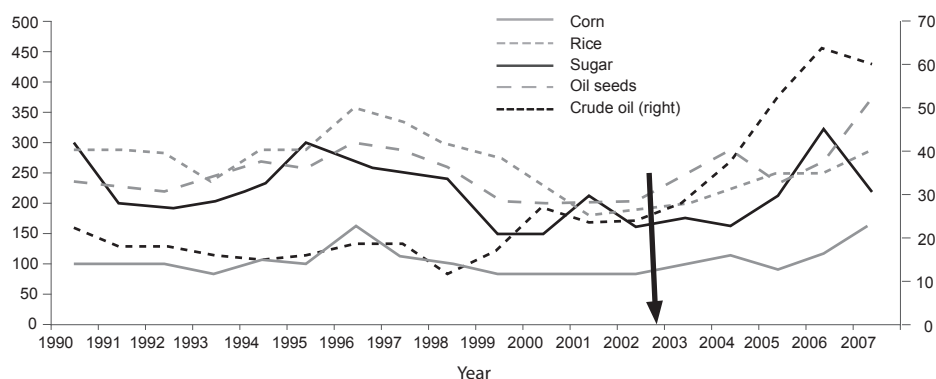
it is a sector not well adapted to the use of coconut-oil fuel substitutes.

Utilities versus the transport sector

A major part of petroleum use in the Pacific is by the transport sector, rather than the electricity-generation sector (World Bank 2005b:40). For example, in Fiji, only 26 per cent of oil consumption is for electricity generation, while some 55 per cent of petroleum use is in the transport sector (World Bank 2005a:X). In Marshall Islands, 68 per cent of petroleum use is for transport and 30 per cent is for electricity generation, while in Vanuatu the shares are 64 per cent and 30 per cent, respectively (World Bank 2005c:VIII). Consequently, if import substitution were the primary focus of government policy then the transport sector should be the primary focus of coconut bio-fuel development.

The problem, however, is that coconut oil is a difficult fuel for use in transportation. The viscosity and the propensity of coconut oil to solidify at temperatures below 22 degrees Celsius can lead to increased engine failure and added maintenance costs, particularly when used in engines not adapted for the use of coconut oil. SOPAC

Figure 4 Prices of crude oil and agricultural fuel substitutes



Source: Von Braun, J., 2007. Promises and challenges when food makes fuel, Presentation to Crawford Fund Conference on Biofuels, Energy and Agriculture, Canberra.



(Furstenwerth 2007:22), in a study carried out in Marshall Islands, found that even in a best-case scenario, using pure coconut oil as a transport fuel resulted in added maintenance costs of between US\$0.25 and US\$0.50/L. Coconut oil often works best as a transport fuel when blended with diesel or converted into an esterified bio-diesel. The transformation of coconut oil into a bio-diesel involves the use of costly and volatile chemicals and the production of glycerin as a waste product. The cost of small-scale esterification of vegetable oil is estimated by SOPAC (2007:11) to be US\$0.30–0.60/L depending on the size of the operation. This process adds a significant cost and technological complication to the production of coconut bio-fuels and reduces its cost competitiveness relative to imported diesel. In addition, securing and safely storing the chemicals required to esterify coconut oil make it ill suited to rural and remote island contexts. Engine manufacturers and insurers tend to recommend using coconut oil in blends of only 5–10 per cent to minimise potential engine damage or clogging of fuel

lines, filters and injectors. While specialised services such as marine transport and municipal bus services have been successful in using coconut oil in higher blends in the Pacific, some clear guidelines covering the limitations of coconut oil as a fuel and the quality controls that need to be in place to ensure consistent fuel quality are required to encourage wider use in the transport sector.

The biggest obstacle to increasing the production of coconut oil is not a lack of demand for the product but shortfalls in the supply of copra. The 'production frontier' for copra imposes some significant limitations on the potential for coconut oil to contribute to oil import substitution and energy independence.

The coconut production frontier

In 2005, SOPAC, with assistance from the University of London, considered the potential production limit to the use of coconut oil as a fuel in the Pacific. It calculated this limit not from current production levels of copra oil but from an estimate of the total amount

Table 2 Combined consumption of diesel and gasoline versus the production potential of coconut oil

Country	Current fuel consumption (million litres)	20 % of current fuel consumption (million litres)	Potential coconut oil production (million litres)*
Fiji Islands	159.4	31.88	17.47
Kiribati	15.9	3.18	3.06
Marshall Islands	94.0	18.8	3.44
Samoa	73.0	14.6	10.92
Solomon Islands	78.0	15.6	7.10
Tonga	32.2	6.44	0.00
Tuvalu	3.1	0.62	0.29
Vanuatu	47	9.4	30.51

* Figures taken from Pacific Islands Applied Geoscience Commission (SOPAC), 2005. *Report of Energy Mission to Vanuatu*, Trip Report 383, Pacific Islands Applied Geoscience Commission, Suva, Fiji.

Sources: World Bank 2005a, 2005b, 2005c



of coconuts available to be harvested in a given year (Table 2).

World prices for copra declined in constant 1990 dollar terms from about US\$1,400/T in 1950 to less than US\$500/T in 2008 (CIDA 2008:2). This decline has significantly discouraged production of copra in the Pacific, as the returns from the difficult work of cutting copra have declined relative to other economic opportunities. There has been less investment in maintaining coconut plantations, ageing of coconut trees and declining productivity per acre—making it even more difficult to generate sufficient income from copra farming.

In 2008, LMC International (2008:6) concluded that, due to the declining production of coconuts in Fiji, there were only sufficient coconuts to substitute for 5 per cent of Fiji's imported fuel with coconut-oil blends—equivalent to producing approximately 4.6 million litres of coconut bio-diesel a year, or 4,250 T of coconut oil, a figure that is barely 25 per cent of the SOPAC figure.

While the relatively high production cost of coconut oil and the low levels of copra and coconut output in the Pacific could thwart the prospects for energy independence, there could be sufficient coconut biomass to produce much more. In particular, there could be sufficient coconuts in some rural and remote areas to meet local energy needs. The key obstacle, however, is not the availability of biomass, but the availability of labour to turn the biomass into a cost-competitive bio-fuel; and, as we will see in the next section, this availability is determined by the returns to labour.

Rural income generation

As a result of increasing standards of living in many Pacific communities, the returns to labour available from copra production have fallen below the 'reservation wage' at

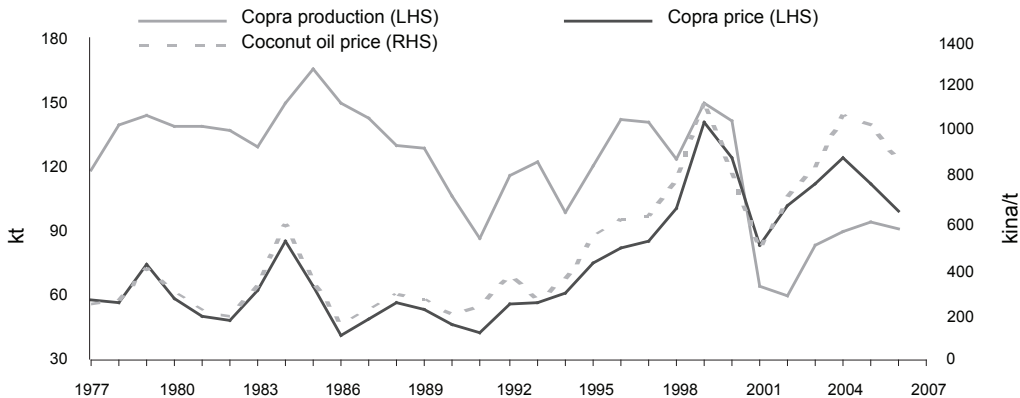
which many Pacific producers are willing to offer their labour. Indeed, the reservation price at which household labour is offered is quite high in the Pacific, owing to the range of subsistence and cash activities each household manages and their ability to reallocate labour between these activities as relative prices change (McGregor and Hopa 2008:46). Where communities are isolated from major markets for consumer goods, such as the rural and remote island communities where copra cutting remains a major activity, demand for cash is often quite limited and occasional; as a result, once sufficient copra or a similar cash crop has been sold to meet household cash needs, labour is reallocated to subsistence activities (McGregor and Hopa 2008:46). This mode of production leads to periods of intermittent supply and can contribute to supply problems encountered by coconut bio-fuel projects.

This problem occurs in Papua New Guinea, where copra production has been closely linked to domestic and world prices (McGregor and Hopa 2008:48) (Figure 5).

McGregor, Warner and Pelomo (2006:65) argue that copra processing is declining rapidly in Pacific countries where the opportunity cost of labour is highest. This is illustrated in Table 3, which presents a comparison between the return to labour from copra at various prices and the prevailing rural wage in Pacific countries. The information suggests that it is only in the Solomon Islands, where alternative employment opportunities are scarce, that copra production is an attractive option. There is, however, significant variation in rural wages within countries, depending on remoteness, which this table is unable to illustrate.

Returns to labour: alternative cash crops

Cutting copra is difficult, physical work that delivers low returns to labour, which has


Figure 5 Responsiveness of coconut supply to price, Papua New Guinea^a


^a Assuming 65 per cent oil yield from copra.

Source: McGregor, A. and Hopa, D., 2008. *Strategic Review of the Coconut Industry and Commodities Marketing in Vanuatu: AusAID component 1*, Australian Agency for International Development, Canberra:48.

Table 3 Returns to making copra compared with rural wage rates in the Pacific

Return to labour as a percentage of the rural wage					
Copra price (US\$)	Solomon Islands (%)	Fiji (%)	Tonga (%)	Samoa (%)	Vanuatu (%)
90	173.3	46.8	22.8	60.8	68.5
105	200.0	54.6	26.6	70.9	80.0
120	226.7	62.4	30.5	81.1	91.5
135	253.3	70.2	34.2	91.2	102.9
150	286.7	78.0	38.1	101.3	114.4

Source: McGregor, A., Warner, R. and Pelomo, M., 2006. Rural growth in the Solomon Islands: opportunities, constraints and strategies, Paper prepared for Agriculture and Rural Development Strategy, World Bank, Washington, DC:65.

made alternative cash crops such as kava and taro increasingly attractive. Taro and kava farming requires relatively few labour inputs for each tonne of output in comparison with copra production. According to the Fijian Ministry for Agriculture and Primary Industry (MAPI 2008b:1), the optimal marketable yield for 1 hectare of taro is 14 T per annum. In contrast, the optimal yield for 1 hectare of kava is 2,500 kg, or 2.5 T, in years four and five of a five-year farming cycle (MAPI 2008a:1). Kava is, however, a

significantly more valuable crop per unit of weight. At the optimal rate of output (averaged across a five-year farming cycle to simplify the comparison between kava and taro), MAPI estimates that a farmer can earn F\$11,403/ha of taro, per annum, in return for 115 man-days of labour (MAPI 2008b:2). The equivalent figures for kava are F\$8,936 and 142 man-days of labour (MAPI 2008a:2).

To compare the return on labour for these two crops with copra, we use the optimal return to labour calculated by SOPAC:



F\$3.60/hour in return for producing 30 kg of wet copra an hour and selling it at the prevailing roadside rate (Zieroth et al 2007:42). If we consider one man-day of copra cutting is equivalent to eight hours of producing copra at this rate, the return on labour is F\$28.80 a day. At the equivalent number of man-days required to produce 1 hectare of taro—115—this will net a copra cutter F\$3,312 per annum. At this rate of return, even if the copra cutter was to produce 30 kg of wet copra an hour—which involves gathering, cracking and scraping some 300 coconuts for eight hours a day, 365 days a year—they would still be unable to reach the financial return gained from farming taro for less than one-third of the effort. At 142 man-days of labour a year—the equivalent effort required to produce 1 ha of kava—the copra cutter would net less than half the reward: F\$4,089.

At these comparative rates of return on labour, where farmers have access to markets for alternative cash crops such as taro and kava, it will be very difficult for a coconut bio-fuel project to attract a sufficient supply of copra. Where farmers have no other cash crops, however, such as on some of the outer islands of Fiji, Kiribati, Vanuatu and Solomon Islands, creating a local market for copra by establishing a coconut bio-fuel project could make economic sense.

Is project location the key to higher rural incomes from coconut oil?

Pacific communities located in rural and remote areas face significant costs in getting their copra to the mill gate, in addition to paying higher prices for the goods they bring to their communities. As world oil prices spiked in 2007 and 2008 and settled higher in 2009, so too did transport costs—raising the cost of living in remote Pacific communities while reducing income received from goods sent to market. This has important consequences for rural income genera-

tion. Woodruff (2007:64) notes that Pacific island countries often face a 'double freight penalty' since the high shipping costs they face mean they pay more for imported fuel and receive lower earnings on coconut-oil and copra exports. Before the product even reaches the mill gate, farmers have to incur significant transport costs; indeed, while the minimum mill-gate price might be F\$500 at the Savusavu copra mill, copra cutters in remote areas of Cakaudrove Province in eastern Vanua Levu report receiving as little as one-third of this amount, once transport costs have been deducted (Ralogaivau 2009:42). Communities located some distance from urban centres, however, such as on outer islands and in rural and remote areas, have the opportunity to turn this 'double freight penalty' to their advantage by producing and consuming coconut oil locally.

The European Union is funding nine coconut-oil bio-fuel projects in the more remote parts of Vanuatu, following a trial coconut-oil bio-fuel power-generation project at Port Olry in the northeast of Espiritu Santos Island. Residents of this village—the third-largest in Vanuatu—face the highest energy tariff in the Pacific: VT150 per kilowatt hour (approximately US\$1.50) (Jensen 2010). The limited demand for electricity has restricted the local market for coconut oil to just 1,430 L a month—equivalent to approximately 15,000 coconuts (Jensen 2010). Given the disparity between the local price for copra (VT30,000/T) and the mill-gate price in Luganville in the south of the island (VT37,500/T), and the vast improvements made to the road between Luganville and Port Olry by the Millennium Challenge Corporation, Port Olry farmers prefer to sell their copra in Luganville and import coconut oil from there as well (Jensen 2010:6). This example indicates that the rural income-generating opportunities—in addition to the local energy savings—of such projects are illusory.



Compounding the problems in developing local markets for copra for local production of coconut-oil bio-fuels are the subsidies paid by Pacific island governments to outer-island producers of copra to supply export markets. An assessment of the viability of the Kiribati copra industry carried out by the Food and Agriculture Organization (FAO) in 2006 identified that the farm-gate price (A\$600/T) on offer from the Kiribati government was more than twice the export price for copra (A\$295/T). Once the cost of handling and shipping from the outer islands to Tarawa was included, the farm-gate price offered for 1 T of copra was estimated at almost three times its market value (Kete 2006:11–12).

The high rate of subsidy paid to support copra production in the remote islands of Kiribati acts as a form of income support for producers with few other income-generating opportunities. It also acts, however, as an artificial barrier to the local production of coconut bio-fuels. The expected return to labour for such producers is likely to be far higher than what could be provided by an economic alternative to imported fuel. To illustrate, if we take SOPAC's estimate that a copra cutter can produce 30 kg of wet copra an hour, it would take 74 hours to generate 1 T of dry copra equivalent (at a moisture content of 45 per cent)—if we exclude the time taken for drying the copra—a return of A\$8.10/hour at the subsidised farm-gate price offered by the Kiribati government (A\$600/T) (Zieroth et al 2007:62). Using SOPAC's extraction rate of 57 per cent, 1 T of copra would produce 570 L of coconut oil—a labour cost of A\$1.05/L of oil (at A\$600/T of copra). While a figure for the cost of 1 L of diesel fuel in the outer islands of Kiribati is unavailable, the retail price of 1 L of diesel oil in Tarawa in 2006 was A\$1.26 (Kete 2006:22). Once the capital costs of establishing and maintaining a coconut-oil mill on a remote island and the labour costs

of running it are factored into the equation, it is difficult to see what incentive producers on the outer islands of Kiribati—among the most remote islanders in the Pacific region—would have to supply to the local market for copra, unless the government undertook a major restructuring of the Kiribati copra industry and removed the subsidy for copra. There would, however, be few livelihood benefits derived from shifting these producers from a subsidised copra market to a local one, if this resulted in lower incomes and, potentially, higher electricity costs.

The competitiveness of a coconut bio-fuel project is determined not only by local labour rates and fuel costs but also by the efficiency of the expelling operation producing coconut oil. Remoteness also creates a wide range of disadvantages: access to maintenance and spare parts; access to skills to manage and maintain the project; and access to markets for any surplus oil. This last point is crucial. Many rural and remote communities are small, with relatively low demand for energy. In seeking to match the project to the community's needs, project designers could install a small oil expeller with relatively low levels of efficiency that requires large labour inputs per litre of oil. This creates the danger of raising the cost of producing a litre of oil above the rate necessary to make it competitive with imported diesel. Project designers could seek to reduce the labour and coconut input costs of a litre oil to the absolute minimum by installing a much larger expeller, but this requires a much larger throughput of coconuts (stretching the capacity of local supply) and creating a huge surplus of oil that has to be marketed outside the community.

Yet, if maximising rural incomes is the priority of governments and donors, there is another option, which is to tap into value-added markets for coconut products.



Increasing incomes by valuing the whole nut

Producing coconut oil to burn as a fuel is a relatively low-value end use of a coconut. There are higher-value markets for 'virgin' oil blends. The direct micro-expeller (DME), or the Etherington Press, is a cold-press process designed by Dan Etherington, an Australian academic, with the explicit purpose of improving rural income-generating opportunities for copra-cutting communities in the Pacific. A significant number of DMEs, which are hand operated and have a price tag of about A\$10,000 a unit, were purchased and distributed throughout the Pacific by donors and philanthropic organisations. It is estimated by Kad and Weir (2008:58) that by operating such a press, a team of five adults can produce 50 L of oil a day at a return of about A\$0.53/L (if the costs of purchasing and maintaining the machine are excluded). While there are currently no Pacific regional or national standard definitions of what constitutes a 'virgin' coconut oil (VCO), there is a growing market for this product as a cosmetic ingredient, a health product and for cooking. Developing such a standard will be important in protecting the rural income-generating potential of this market, as small, hand presses operated by rural Pacific island producers would be simply unable to compete with larger, mechanised units operated by their competitors in Asia.

Pacific island economies could maximise their returns from their coconut resource by transforming their production system from one oriented towards oil production to one oriented towards utilising the numerous by-products of oil production: the 'whole-nut' approach. The 'whole-nut' concept, pioneered by Divina Balwalan of the Philippine Coconut Authority, is an integrated system of coconut processing in which all parts of the coconut fruit are

converted into valuable products. In her review of the Fijian copra industry, Balwalan (2008:65) estimates that the highest income gains to be generated from the industry would come from properly de-husking nuts so that the coconut husk can be sold and processed into value-added end products: coir for the textiles industry; coconut shell for charcoal filters; bio-char to improve soil fertility; and fuel for bio-gasifiers to turn into electricity. From the de-husked whole nuts, communities should also be encouraged to produce and sell VCO, coconut vinegar from coconut water and dried coconut milk for use in cooking (Balwalan 2008:70). Raising the value of de-husked whole nuts from a few cents to one dollar or more would provide rural communities in the Pacific with a more valuable end market for their products—sufficient to surpass the additional costs associated with transporting whole nuts from remote communities. Such a transformation would, however, require a significant commitment from national authorities, including training and sensitisation of communities to encourage them to change their harvesting techniques. At the same time, it would require significant market research and development to link coconut producers to these emerging markets. It would also require significant investment to develop the processing facilities required to transform these coconut by-products so as to achieve the quality and consistency required by overseas markets. Given that such a 'whole-nut' transformation has already been undertaken by the Pacific's near competitors in the Philippines, Indonesia and India—countries that enjoy significant economies of scale and lower-cost transport links to major markets, in addition to possessing the local industry to provide additional demand—it is difficult to see where the Pacific might be able to carve out sufficient market share. Through careful branding and certification—where



this is shown to be an advantage in the eyes of consumers—the Pacific might, however, be able to take advantage of ‘niche’ markets for their coconut by-products among less price-conscious consumers.

For those communities unable to tap into markets for value-added coconut products, coconut oil can provide a locally produced alternative to power rural electrification. This opportunity is, however, limited by a number of factors, which are explored in the next section.

Rural electrification

Poor access to electricity is common in the rural areas and outer islands of some Pacific island countries (UNDP 2007a:11). Many Pacific island countries have their non-urban populations dispersed over numerous small islands, making it difficult to provide universal access to energy via an island-wide grid. Typically, off-grid electricity supplies are met by diesel mini-grids connected to generators, which are expensive on an energy-unit-cost basis, and which suffer unreliable, intermittent supply (UNDP 2007a:15).

Pacific governments and development partners have sought to justify investment in coconut bio-fuel production as a means of increasing access to electricity for those rural and remote communities currently off the main power grids (and with little prospect of being joined up soon) by lowering fuel input costs. The implementation experience of small-community electrification using coconut bio-fuel has, however, been mixed.

There are several technical issues that must be addressed during the project design phase, including the choice of the technology and control system; the method used for drying the copra needs to be capable of reducing moisture and acidity levels to

a minimum; and the oil needs to be free of solids and other contaminants. Outer islands and remote parts of the Pacific are difficult environments in which to maintain machinery. When equipment breaks down, parts are difficult to acquire, and local communities are often ill trained in how to maintain or repair what has been installed. Relying on one or two local residents is ill advised, as people often migrate or move away, leaving a skills deficit. In addition, poor-quality copra-drying techniques can lead to engine carbonisation and failure. In such an environment, it is important to ensure outside assistance is available to communities. By partnering with the private sector or government rural electrification departments, where available, to ensure that continuing maintenance and repair is a shared responsibility, coconut bio-fuel projects will contribute to their own sustainability.

Sufficient training needs to be provided to the community to enable them to use and maintain the units that are installed, while access to external maintenance support is also a continuing requirement. The additional maintenance complications and costs associated with the use of coconut-oil bio-fuels in many engines are exacerbated by this lack of support—and can contribute to its unsuitability as a fuel for rural electrification. As was identified earlier, however, the major issue relates to matching the expelling technology with local conditions.

The most appropriate technology?

While access to maintenance and good management of the local project are important, the key issue affecting rural electrification schemes using coconut oil is whether oil can be produced locally at a price competitive with imported diesel. This is determined by the local cost of labour and coconuts, and the supply of coconuts and labour inputs required.



Local production of coconut oil has been tried, with varying levels of success, with the distribution of DMEs and other hand-operated oil presses and screw presses. Many of these presses were, however, designed for the production of a far more valuable end product: VCO, which retails at three to four times the final price of coconut oil consumed as a fuel. Kad and Weir (2008:52) estimate that the retail price for 1 L of VCO in Suva is F\$8.45. Each DME unit employs four to six adults to produce between 30 and 50 L of oil a day. Thus, there is a high labour cost component in the production of each litre of oil. Increasing the scale of production is necessary to make coconut-oil bio-fuels cost competitive with imported diesel, even in the most remote Pacific communities.

Another, more efficient example is the Axis hydraulic press. Rather than requiring the strength of a number of employees to physically press the coconut oil from the copra, the hydraulic press does the same job more quickly and more effectively using hydraulics. This reduces the number of nuts required to provide one litre of oil. A Fijian group based on the island of Moala in the Lau Group, Origins Pacific Limited, found that after moving from DMEs to an Axis expeller, they almost doubled their oil production—from 1,067 to 2,040 L a month, despite increasing the daily input of nuts by only 28 per cent (Origins 2009). As a result, they were able to almost halve their production costs per litre. At a cost of F\$2.81/L, however, before adding marketing and administration expenses, even an automatic hydraulic press is unable to produce coconut oil at a price capable of competing with imported fossil fuels.

A worthwhile innovation in the Pacific island coconut industry has been the introduction of Indian Tinytech cold-press mills. Tinytech mills are well suited for a small-scale, bio-fuel operation, as shown by the experience of Buka Metal Fabricators on

Bougainville. The capital cost of Tinytech cold-press mills is low (approximately €7,350 delivered)¹ and throughput is reasonably high; the mills are capable of handling about 600 kg of copra in a day. The oil extraction rate is lower than that of a conventional copra mill (about 52 per cent oil); therefore, it is capable of producing some 300 L of oil a day—six times the production of a DME or approximately three times the productivity of an Axis press. Tinytech mills use far less labour than DMEs (three people are required to produce about 300 L of oil compared with six people to produce 45 L). This lower manpower requirement contributes to the much lower production costs per litre of oil. Similar to the DME and the Axis Press, however, with the Tinytech mill, it is still difficult to produce a litre of coconut oil at a price that is competitive with imported fuels, even in the most remote location. To reduce production costs of coconut oil to a price that is competitive with imported fuels requires a further increase in the scale of production.

In 2006, the Pacific Island Energy Policy and Strategic Action Planning Project (PIEPSAP) commissioned a study of the feasibility of establishing a medium-sized coconut-oil bio-fuel facility on Fiji's most remote island, Rotuma.

Rotuma is an island of 525 households, located 640 km northwest of Suva. As a result of its long distance from Suva—the arrival point for all fuel imported into Fiji—Rotuma has the highest fuel costs of any region in Fiji (Zieroth, Gaunavinaka and Forstreuter 2007:10). In August 2008, at the height of the oil price spike, diesel retailed on Rotuma Island for F\$2.59/L; however, by August 2009, the price had declined to F\$1.87/L (compared with F\$1.67 in Suva) (Government of Fiji 2009).

A detailed analysis of Rotuma's total harvestable nut production revealed that it was capable of producing five million



nuts a year (Zieroth, Gaunavinaka and Forstreuter 2007:40). With 1.5 million of these nuts already going towards local consumption, Rotuma would be left with 3.5 million nuts a year—enough to produce 690,000 L of coconut oil (or 635,000 L of diesel oil equivalent)—more than three times the estimated annual fuel consumption of the island (Zieroth, Gaunavinaka and Forstreuter 2007:81). The PIEPSAP feasibility study concluded that by scaling up production to 100,000 L of coconut oil a year, the Rotuma project would be able to produce coconut-oil bio-fuels at a price competitive with imported diesel (Zieroth, Gaunavinaka and Forstreuter 2007:82). In reaching this conclusion, however, PIEPSAP seriously underpriced the local reservation price for labour by assuming that it would secure the needed supply of green copra at the current roadside price of F\$0.12/kg (Zieroth, Gaunavinaka and Forstreuter 2007:4).

The PIEPSAP feasibility study identified that Rotuma's cash economy is driven by three sources of income: remittances, government salaries and the export of copra (Zieroth, Gaunavinaka and Forstreuter 2007:22). Rotuma's copra cutters were estimated to have received a total of F\$154,000 in 2005—or F\$293 per household. By way of comparison, remittances to Rotuma from just the main Fijian island of Viti Levu totalled approximately F\$1 million a month in 2007 (excluding informal transactions carried on outside Western Union)—some F\$500 a month for every Rotuman living on the island (Hanan 2008:234).

This comparison illustrates the superiority of remittances as a source of cash income on Rotuma and its potential to satisfy the occasional cash needs traditionally provided by copra production identified by McGregor and Hopa (2008). The prevailing socioeconomic conditions on Rotuma dictate that a significantly higher return to labour would be required to attract a

supply of coconuts sufficient to justify the installation of a F\$150,000 mini-mill; yet to offer such a return to labour would render the price of its oil output uncompetitive with imported diesel. Consequently, this project was unable to proceed.

The Government of Fiji is currently embarking on a policy to install coconut expellers with approximately half of the oil production capacity of the one mentioned above, and with demand from significantly smaller local populations, in up to 42 locations around Fiji (Interview, V. Vorovago, Biofuels Unit, Fiji Department of Energy, Suva, 2009). The success of this endeavour will rest on four factors: 1) being able to motivate local labour at sufficiently low wages to supply sufficient throughput of coconuts to keep the expeller operating on a cost-effective basis; 2) finding markets for the large volume of oil surplus to local demand that these projects will generate; 3) being able to access maintenance assistance when needed; and 4) maintaining good management, particularly financial management, of the project to ensure oil is supplied on a user-pays basis. Yet, where the needed maintenance support is divided between a number of consecutive or concurrent projects, where energy prices are kept low through government subsidy or other interventions, where reservation labour costs are high as a result of the provision of remittances or access to markets for higher-value or value-added products, then coconut bio-fuel rural electrification projects are unlikely to be sustainable.

Lessons learned

There has been a range of evaluations and feasibility assessments of the potential use of the Pacific's coconut resources for energy, particularly through the production and use of coconut oil as a liquid fuel.



Many of these assessments, however, have failed to appreciate the real cost of labour in the Pacific. Moreover, past assessments have focused on arbitrary determinants such as the world price of a barrel of oil; they have predicated the feasibility of coconut bio-fuels on the price of a barrel of oil becoming sufficiently expensive. Yet what such efforts fail to appreciate is that the close and increasing correlation between world oil prices and the price of coconut oil means that when world oil prices rise, so do the prices of coconut oil and copra.

Remoteness can be an advantage. By locating the local production and consumption of coconut oil in areas that suffer from high freight costs, a project can benefit from the correspondingly high price of imported diesel as well as low producer incomes. This local labour cost limitation effectively eliminates, however, the feasibility of implementing sustainable coconut bio-fuel projects in a majority of Pacific island countries, and in a majority of areas within them. Polynesian and Micronesian countries (apart from the outer islands of Kiribati), and much of Fiji, are unlikely to be enticed into copra production for bio-fuels at the rates of returns to labour that need to be on offer to make these projects price competitive with imported oil. Yet much of Melanesia—Papua New Guinea, Vanuatu and Solomon Islands—has local labour and imported fuel costs that make coconut bio-fuel production economically competitive; and so it is here that the greatest potential for rural income generation, rural electrification and import substitution lies (accompanied by the right management and maintenance support).

Coconut bio-fuels are unlikely to revitalise the Pacific's copra industries. Transforming the national coconut industry into one that values the whole nut rather than just the oil is critical to increasing the value of coconuts and the returns that can

be received for farming them. Until the coconut-processing industries of the Pacific are transformed to value the whole nut, the economics of copra production for Pacific communities will remain largely the same. Returns from alternative cash crops such as kava and dalo will remain higher; and, in many cases, remittances could maintain an artificially high reservation rate for labour. Hence, where improving rural incomes is the priority of governments and development partners, communities should not be enticed back into copra production by the promise of cheaper electricity. Local coconut-oil production for local consumption should be viewed as a 'last resort' for those communities whose distance from markets makes it difficult to shift into the production of alternative cash crops.

Those communities with access to alternative cash crops or markets offering superior returns to labour should continue to direct their labour towards these activities and use their additional income to purchase diesel fuel or competitively priced coconut oil from other communities without the same income-generating opportunities.

The potential for coconut oil to replace fossil fuel oil—the region's major import—is limited. Indeed, donors and many Pacific island governments could find that the return on investment is greater from other sources of renewable energy, as well as from the introduction of efficiency measures to reduce the consumption of energy in the Pacific islands. This discussion is, however, beyond the scope of this article.

Note

- ¹ According to the TinyTech India web site (www.tinytechindia.com). The price given is for delivery to Port Moresby.



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